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Exterior Brick Masonry Walls:

Causes of and Solutions to Inevitable Deterioration

Scott D. Chamberlain

The history of brick, man's oldest manufactured building product, is long and storied. Used in construction for thousands of years, it reflects the evolution and variety of our ever-changing constructed world.

The first bricks were made from the mud of riverbanks and baked in the sun, as long ago as 10,000 B.C. Chopped straw and grass were added to prevent distortion and cracking. Around 4,000 B.C., brick manufacturers began producing uniform shapes and firing them in kilns. Firing caused the clay particles to bond chemically, hence improving brick's durability.

Brick's aesthetic appeal and diversity is undeniable. From the historic red schoolhouses that dot the countryside to the landmarked Chrysler Building clad in glazed brick, from Thomas Jefferson's Monticello to the low-rise buildings of contemporary suburban office parks, brick is represented in an astounding array of architectural styles.

Aside from its visual appeal, brick has great longevity. It withstands the tests of time and Mother Nature. Take, for example, The Great Wall of China. Its construction began in 221 B.C., and it still stands strong today, even where it leans at angles as drastic as 70 degrees, across some of China's most severe and mountainous terrain.

As with all building envelope systems, deterioration is inevitable. The key to sustaining brick masonry exterior walls for as long as possible is preventative maintenance and repair. Preventing minor deterioration from escalating into bigger problems will ensure a structure's longevity.

Form and Function

Brick masonry walls consist of uniformly shaped and sized bricks that are laid in courses with mortar joints. A singular vertical section of brick masonry, one unit in thickness, is referred to as a *wythe*. Bricks can be of various colors and hardnesses. They may be glazed, pressed or molded, or customized to suit the design requirements for a particular structure.

Bricks need to conform to a number of criteria in order to be effective building blocks. They should be durable and meet the required minimum compressive strength dictated by the design. They should not exceed maximum water absorption and saturation guidelines, should pass

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The landmarked Chrysler Building in New York City is clad in glazed brick. Though the towering structure is perhaps best known for its shining spire, its facade features intricate, automobile-inspired brick patterns.

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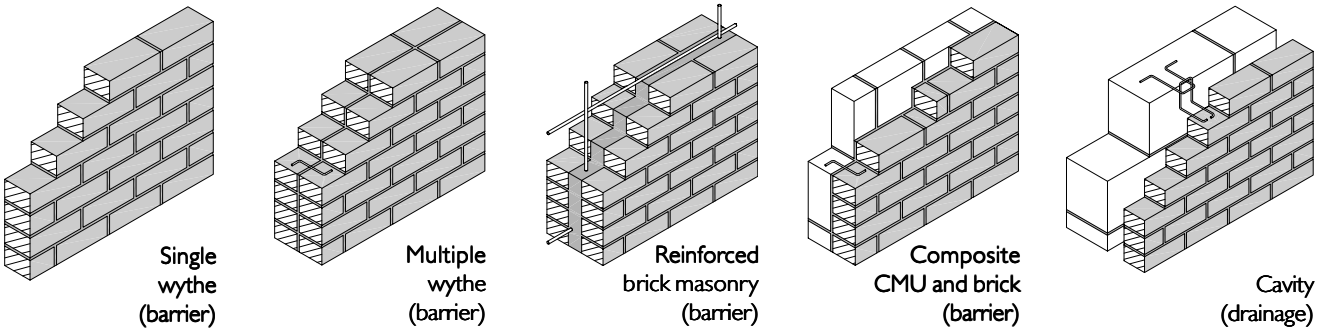
Figure 1 Types of Brick Masonry Walls



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freezing and thawing tests, and should meet the weathering challenges of a region.

For example, a brick specified for a structure in hot, dry southwestern New Mexico would likely fail in New England and other northern climates where buildings are subjected to a wide range of climatic conditions, including freeze-thaw cycling.

Waterproofing for Brick Masonry Exterior Walls

The primary role of the building envelope is to separate and protect an interior space created by man from the natural environment. First and foremost, it holds the forces of Mother Nature at bay by sealing a building from the elements: wind, rain, snow, ice, thermal conditions (heat/cold).

Water is a constant threat to the building envelope's ability to protect interior space; it is a principle cause of deterioration in building envelope systems, and it is no different in brick masonry exterior walls. It is therefore critical that, in addition to the requirements of structural design, an exterior brick masonry wall be designed to resist water infiltration to the highest degree possible. Successful waterproofing of exterior brick masonry walls relies upon a clear understanding of the means by which water infiltrates a wall system; the proper construction of a selected wall system and its suitability for a structure's particular climate; the appropriate use of various types of specified materials, such as brick and mortar; and, methods for expelling moisture that has entered a wall, by means of flashing and weep systems.

Types of wall construction

In terms of waterproofing, exterior brick masonry walls can be classified as either *barrier* or *drainage* walls.

Barrier walls

More common prior to the development of cavity walls, barrier walls are constructed of solid masonry without the use of a drainage cavity. They may be constructed of multiple wythes of brick, or they may be composite walls constructed of brick masonry combined with a variety of masonry materials such as Concrete Masonry Units (CMUs) or terra cotta block. Barrier walls may also be load-bearing walls reinforced with steel to support or help support a structure. Single wythe barrier walls are generally constructed from a masonry unit that is wider (deeper) than a standard unit making the wall more impervious to water penetration. However, single wythe barrier walls are often not as successful at preventing water infiltration as drainage or multiple wythe barrier walls.

Multiple wythe brick barrier walls that are three wythes or more are designed to prevent water infiltration through mass. While not always successful, the amount of water that the wall is allowed to absorb over a period of time should be less than can be dissipated in the same period, keeping water from reaching the interior surface of the wall.

Narrower multiple wythe barrier walls and composite walls depend on a collar joint to provide a barrier within the wall. The collar joint, grouted solid with mortar, is the joint between the exterior wythe of masonry and the backup masonry. The collar joint blocks water that penetrates the face of a wall. That water then either follows the collar joint down to the flashing level where it is expelled through the bed joint and/or weep holes, or it dissipates out through the face of the wall.

Drainage walls

Drainage walls are designed with a cavity within the wall. The cavity is located between the outer wythe of brick masonry and the back-up material that may consist of brick, CMUs, metal or wood stud framing.

Like the collar joint in a barrier wall, the cavity is designed to stop the penetration of water that enters the face of a wall from traveling to the interior, backup portion of a wall. However, instead of forming a physical barrier, the cavity forms a break that water has difficulty crossing. When water penetrates the face brick, it runs down the interior surface of the exterior wythe of brick to the flashing level where it is expelled through the bed joint and/or weep holes.

In order for drainage walls to be effective, careful consideration must be given to design details for flashings prior to construction. Improperly installed flashings *will* fail.

Furthermore, the cavity must be kept clean and free of debris both during and after construction, as mortar droppings and other construction debris in the cavity may clog weep holes. Mortar, debris, and improperly designed brick ties may also bridge the cavity, allowing water to penetrate the backup above the level of the waterproofing.

Symptoms and Causes of Deterioration in Brick Masonry Wall Construction

The symptoms of deterioration in brick masonry wall construction are generally easily detected by visual inspection. Symptoms include:

- staining and efflorescence;
- cracking;
- spalling;
- deteriorated mortar joints;
- loose, displaced or crushed brick;
- mildew, a fungus; and,

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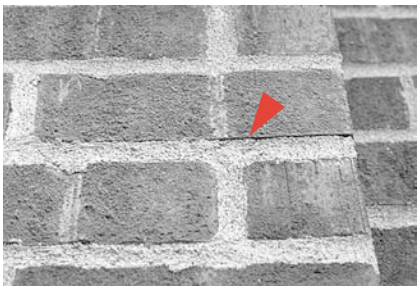
The Roles of Relieving (Shelf) Angles and Soft Joints

Building components expand and contract with changes in temperature and moisture content. Relieving (or shelf) angles are necessary to accommodate this movement in masonry walls. If a relieving angle is omitted, cracks will develop where the brick is restrained as the brick grows and the backup shrinks.

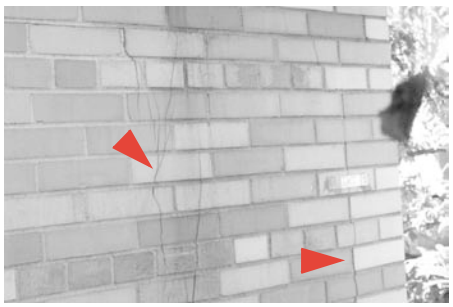
Soft joints should be constructed at relieving angles to create relief for brick's expansion. If soft joints at relieving angles are not properly constructed, the brick will be crushed and water will be allowed into the wall system. Control and expansion joints are needed vertically as well. Without expansion control, brick will slide off of the relieving angle.

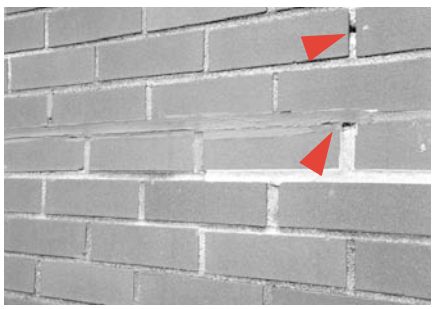
▲ What happens when relieving angles are omitted? Cracking. Here, brick has expanded; the backup has shrunk; and, cracks have developed where the brick is restrained at balconies, windows and vents.



▲ These mortar joints appear to be properly tooled, yet there is a lack of adhesion between the mortar and the brick. The cause? Either the mortar had begun to set too early or the brick was very dry at the time of repointing. A repointing project is only as good as its weakest component.

▼ Below left, cracking through brick masonry wall. Below middle, eroded mortar joints below this cornice . Below right, inadequate partial repointing has left many mortar joints vulnerable to water intrusion.





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- vegetative growth, such as moss in mortar joints.

Mortar deterioration

Mortar is as integral to brick masonry wall construction as bricks themselves. Mortar holds a masonry wall together and serves as a barrier against the passage of air and water. Some common causes of mortar deterioration include improperly tooled joints; water infiltration that washes away mortar's soluble salts, reducing its impermeability; and, the eroding force of wind and rain.

Loss of mortar leaves an exterior wall vulnerable to water infiltration. Repointing is required when the bond between the mortar and the brick is broken, when mortar has crumbled from the joint, when hairline cracks appear in the mortar, and when mortar has eroded to expose the back-up wall material.

Efflorescence

Efflorescence occurs when water washes soluble salts out of mortar and onto the surface of brick. White stains and/or build-up of white, crystalline structures develop on brick surfaces as the water evaporates.

Cracking and spalling

Expansion from thermal changes, from water absorption and from freezing and thawing of retained moisture causes cracking and spalling (the breaking off of the face of brick) in brick masonry walls. The corrosion of embedded steel reinforcing in masonry walls may also lead to cracking and spalling of brick.

The usual suspects: failed or inadequate flashing and weep systems

A key component in both drainage and barrier wall systems, flashing is an impermeable membrane that forms a horizontal barrier that stops the vertical movement of water and directs it out of a wall system.

Weep holes provide a direct route for water to exit a wall. In order to be effective, weep holes should be located directly above *all* areas of flashing. Installing weeps too far above flashing is a mistake, as water may collect beneath the weeps and back up at the flashing.

A flashing and weep system is an integral part of an exterior brick masonry wall system and key to expelling water from within a wall. However, unless properly installed and maintained, flashing and weeps can be a cause of water infiltration and damage to a wall.

When Flashing and Weep Systems Fail...

Counter-clockwise from left:

- Leaks in the flashing at this window lead not only to water infiltration into the building, but also to corrosion of steel lintels and deterioration of the anchorage system that supports the brick face.

- Efflorescence at brick masonry under cornices and belt courses is a sure sign of water infiltration through leaking flashing or open butt joints in the stones above.

- The bed joints above the through-wall flashing at the base of this wall have been sealed over, trapping moisture within the wall, causing spalling of brick.

- The bed joints above the through-wall flashing have been sealed over at this roof parapet, causing water retention. Note moss growth and efflorescence.

In a drainage or barrier wall system, flashings are typically located where intersecting elements have interrupted the cavity or collar joint within a wall. These locations include continuous relieving angles; wall openings such as windows or louvers; and continuous horizontal elements like stone or concrete cornices, belt courses, and water tables. Leaks in the flashings at these locations can lead not only to water penetration into the building, but also to corrosion of the steel lintels and deterioration of the anchorage systems that support the brick façade or masonry appurtenances. Corrosion of steel lintels is often indicated by spalling of brick at the jamb of the opening just below the lintel, loss of mortar around the embedded steel, or rust staining on the face of the brick.

Efflorescence at brick masonry under cornices and belt courses is a sure sign of water infiltration through leaking flashing or open butt joints in the stones above. Water washes the soluble salts out of the mortar onto the surface of the brick where it crystallizes through evaporation of the water, forming what appears to be white fuzz on the surface of the brick. The loss of soluble salts eventually affects the permeability of the mortar allowing water to permeate the joints, which can cause further deterioration of the mortar and brick.

Through-wall flashings are also typically found in roof parapets and at the base of walls where they extend out of the wall to form counterflashings over the termination of a roofing system. These systems are often mistaken for

(continued on page 6)

Figure 2 Masonry Facade Inspection Checklist*

Area	Condition	Facade			
		A	B	C	D
Masonry Walls	Deteriorated mortar joints				
	Cracked bricks				
	Efflorescence				
	Loose bricks				
	Missing/clogged weep holes				
	Vegetative growth				
	Deteriorated sealant joints				
	Structural deterioration				
	Failing expansion joints				
	Surface spalling				
	Stains				
	Water penetration				
	Vertical cracks at building corners				
Windows	Deteriorated sealant joints				
	Rusting/sagging lintels				
	Cracked/spalled sills				
	Deteriorated mullions				
Parapets	Damaged parapet copings				
	Deteriorated parapet walls				
Flashing/ Counterflashing	Bent flashing				
	Missing flashing				
	Open lap joints				
	Stains				
Caps/Copings	Cracks				
	Loose or open joints				
	Displacement				

* *Periodic inspections are key to making timely and appropriate repairs. This list indicates what to look for during inspections.*

The Goodwin Hotel's Award-Winning Facade Restoration

The Queen Anne style Goodwin Hotel in Hartford, Connecticut was originally designed as an apartment building in the late 1800s by New York architects Kimball and Wise. Constructed using masonry bearing walls, the structure's exterior façades were accentuated with ornamental brickwork and terra cotta. During the late 1980s, the interior of the building was demolished, leaving the exterior walls for incorporation into a new hotel facility.

Following completion of the hotel, symptoms of masonry distress—spalling, cracking, efflorescence—became apparent at the structure's original exterior walls and remained persistent after initial repair and restoration efforts. The owner called upon Hoffmann Architects to investigate the causes of this deterioration and to develop a program to restore the exterior of the building.

The firm's comprehensive restoration program consisted of the complete reconstruction of the upper exterior walls and roof of the structure. These repairs included the replacement and/or restoration of damaged brick and ornamental terra cotta, complete repointing of all mortar joints and the application of a water-repellant coating.

Though faced with significant challenges—the customization of 14 replacement brick shapes, the task of repointing narrow mortar joints, and the careful phasing of work to accommodate not less than 80% occupancy of the hotel's guest rooms at any time—the firm designed a restoration program that has provided the owner with a watertight building envelope while successfully maintaining the aesthetic and historic features of the Goodwin Hotel's original design.

The Goodwin Hotel Hartford, Connecticut. The hotel *after* Hoffmann Architects' award-winning restoration.

Severely deteriorated brick at the hotel necessitated complete reconstruction of the upper exterior walls and replacement of face brick at lower areas.

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reglet-mounted counterflashings, the sole purpose of which is to provide protection for the roof flashings. Bed joints above properly installed through-wall flashings normally consist of mortar, with or without weeps, and allow water to filter out of the wall. Bed joints that also serve as sealant joints require a weep system to allow water to exit the wall. Frequently, these joints are mistakenly viewed as a source of water infiltration and are sealed over, trapping moisture within a wall and consequently causing further deterioration.

The Solutions

Periodic inspections and routine maintenance

Periodic inspections are necessary in order to make timely and appropriate repairs to areas of deterioration at brick masonry walls. The Masonry Facade Inspection Checklist on page 5 provides indicators of deterioration to look for when conducting an inspection. A qualified design professional will be able to recommend rehabilitative action to prevent these symptoms from developing into more severe, more costly, building envelope failures.

During inspections, it should be kept in mind that water is most likely to penetrate brick masonry walls through:

- failed mortar joints;
- parapets and copings;

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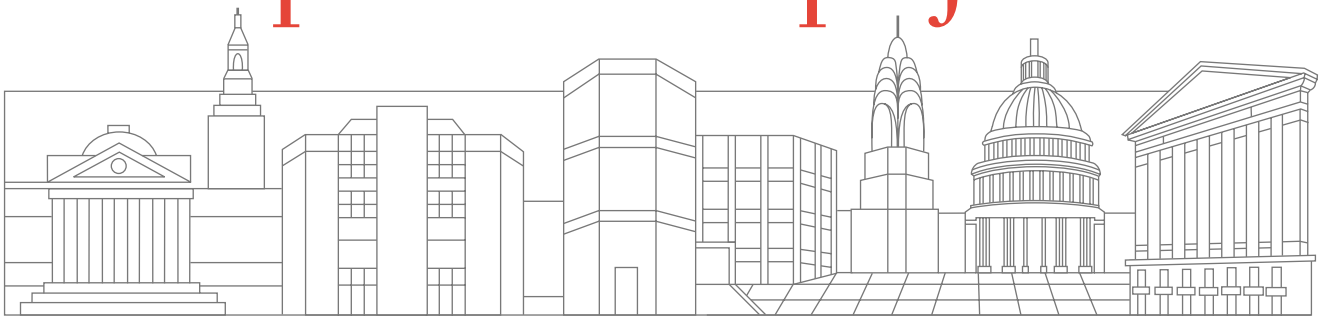
representative projects



Brick Masonry Rehabilitation

The following representative projects included brick masonry rehabilitation.

Chrysler Building
New York New York
Spire and Facade Restoration

JP Morgan Chase and Co.
New York, New York
Building Envelope Survey and Facade Restoration
15 Broad Street
37 Wall Street
43 Exchange Place

The Goodwin Hotel
Hartford, Connecticut
Facade and Roof Restoration

Columbia University
Hammer Health Science Center
New York, New York
Facade Investigation and Rehabilitation

New York City School Construction Authority
Long Island City, New York
Exterior Building Maintenance Manuals and Facade Rehabilitation

Congregational Church
United Church of Christ
Naugatuck, Connecticut
Steeple and Parish House Rehabilitation

Fairfield Public Schools
Fairfield, Connecticut
Building Envelope Rehabilitation

University of Maryland
Eastern Shore
Student Development Center
Princess Anne, Maryland
Facade Rehabilitation

25 Sigourney Street
Hartford, Connecticut
Building Envelope Survey and Rehabilitation

The Smithsonian Institution
The Renwick Gallery
Washington, District of Columbia
Water Infiltration Remediation

Columbia University
44 Morningside Drive
New York, New York
Building Envelope Rehabilitation

IBM Corporation
Southbury, Connecticut
Building Envelope Rehabilitation

University of Connecticut
Dodd Archives Research Center
Storrs, Connecticut
Building Envelope Rehabilitation

The George Washington University
Stuart Hall
Washington, District of Columbia
Facade Rehabilitation

Verizon Communications
New York, New York
Local Law 11 Repairs and Building Envelope Rehabilitation
Multiple Buildings in Brooklyn and Manhattan

Yale University School of Medicine
Sterling Hall of Medicine
New Haven, Connecticut
Building Envelope Rehabilitation

Scholastic Publishing
New York, New York
Building Envelope Rehabilitation
555 Broadway

Pfizer, Inc.
Global Manufacturing Facility
Brooklyn, New York
Building Envelope Rehabilitation

1000 Thomas Jefferson Street, NW
Washington, District of Columbia
Facade Rehabilitation

Capital Community College
(Historic G. Fox Building)
Hartford, Connecticut
Facade and Roof Rehabilitation ■

IBM Corporation Advanced Business Institute Palisades, New York. Hoffmann Architects' project work included masonry rehabilitation of facades at this corporate training facility.

Repointing Deteriorated Mortar Joints

The most common and inevitable brick masonry problem is deteriorated mortar joints. Proper repointing of mortar joints requires:

- careful removal of deteriorated, inappropriate or loose mortar;
- cleaning the joints of old mortar and dirt; and,
- installation of an appropriate—flexible, yet durable—mortar.

During mortar installation, proper tooling of joints will ensure that mortar fills them completely. Ideally, they will be tooled to achieve a concave (or *rodded*) surface that is optimal for directing water *off* of a brick face (*See Figure 3*). Improper tooling allows water to rest in joints, threatening to enter masonry walls.

Figure 3

Concave/rodded tooling of mortar joints is recommended as the most effective tooling for preventing water infiltration.

(continued from page 6)

- sills, cornices and belt courses;
- areas of failed/inadequate flashing; and,
- failed sealant joints.

In addition to periodic inspections, routine maintenance plays an important role in the longevity of exterior brick masonry walls. Not only should cavities be kept clean and free of debris during and after construction, facades should be kept clean of pollutants and free of vegetation, such as vine growth, which can penetrate the masonry, facilitating water infiltration.

Conclusion

Exterior brick masonry walls are durable, but they are susceptible to inevitable deterioration, as are all building envelope systems. Understanding and resolving the root causes of deterioration is critical to the development of lasting rehabilitation solutions. Routine inspections and preventative maintenance and repairs are crucial in promoting the longevity of these facades. By inspecting walls on a routine basis, areas of minor deterioration can be detected and repaired before they escalate into more severe, and more costly, problems. ■

JOURNAL is a publication of Hoffmann Architects, specialists in the rehabilitation of building exteriors. The firm's work includes investigative and rehabilitative architecture/engineering services for the analysis and resolution of problems within roofs, facades, glazing, and structural systems of existing buildings, plazas/terraces, and parking garages.

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